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$25 10 GHz Signal Generator

Do you need a way to verify that your 10 GHz receiver is working? Do you need an inexpensive signal source for other microwave testing? This project may be the easiest answer you will find.

Microwave Amateur Radio is interesting and quite educational. New commercial microwave test equipment is expensive, though. For example, a new Keysight analog signal generator starts at $25,825 as typically configured.[1] That is why we go to hamfests and read articles like this!

To build a complete 10 GHz signal source we will use an inexpensive miniature motion sensor module, the ST Electronics HB100.[2] All we are going to do is add power, run a coax line from the transmit feed network in the HB100 to an SMA connector and put it all in a plastic box. Then adjust the frequency and we're done!

Joe Theobald, AC7JD, originally wondered whether the HB100 could be used as a test source while he was building his 10 GHz station. He noticed that the HB100 is widely available and essentially a 10 GHz Doppler radar transceiver. We bought several for about $3.50 apiece on eBay.[3] (I have seen others advertised from $1.50 on eBay to $10.00 on Amazon.[4]) I began to think that I could use a 10 GHz signal source that I could put in my shirt pocket for around $25. This article describes that inexpensive, simple 10 GHz signal source.

[1]Notes appear on page 38.

Requirements

I wanted a signal generator for rover use, to determine if my rig was working. Joe, AC7JD, suggested this could also be used as a source for testing cable loss. (Testing an X Band radio's cables is a really good idea before you go into the field!) This led to my requirements for an HB100 based source:

- Low cost — goal of less than $25 for the whole signal generator.
- Generates a signal between 10.368 and 10.370 GHz (most amateurs operate here and this is where my transverter is designed to work).
- Radiates to free space.
- SMA output for lab tests.
- Small and portable.
- Can run off a 9 V battery or 12 V supply.
- Fits in my shirt pocket.

Table 1
HB100 Characteristics

Parameter	*Minimum*	*Typical*	*Maximum*
Frequency (GHz)	10.520	10.525	10.530
Radiated Power (dBm)	12	15	20
Supply Voltage (V dc)	4.74	5.00	5.25
Current (mA)		30	40

Table 2
Parts List

Item No.	*Reference*	*Description*	*Source*	*Notes*	*Cost*
1	V1	9 V battery			
2	S1	Miniature push button switch	Flea Market		$1.00
3	PW1	LM7805	RadioShack		$1.99
4	RF1	HB100	eBay	Motion sensor module	$5.50
5	J1	SMA socket	RF Parts		$3.95
6		Enclosure	Radio Shack	3x2x1 project box	$3.49
7		Front panel	Lowes	Acrylic sheet, 8x10, smaller if you can find it	$4.24
8		9V battery connector	RadioShack		$2.99
				Total Parts Cost	**$23.16**

Design

The heart of this project is the microwave sensor module. Key characteristics of the HB100 are shown in Table 1.

This module is designed to be used in a short range motion detector. It uses a dielectric resonator oscillator (DRO) as the internal signal generator. This acts as both the transmit signal, which goes to the two transmit patch antennas, and as the local oscillator signal for the receive mixer. That mixer is fed a signal from the two receive patch antennas. Because the same signal is used for both transmit and receive, it can wander around and still work quite well in the Doppler radar front end configuration of the HB100.

The DRO is an inexpensive way to get X band energy if its performance meets the system needs. It does for a motion detector and for the requirements of this project. I wouldn't recommend a DRO as a general replacement for an oven-controlled crystal oscillator (OXCO), however. The HB100 sold for use in the United States is tuned 10.525 GHz, just above the US Amateur Radio band, but can easily be retuned to 10.369 GHz.

In his online paper, Walter Clark describes how to make a short range transceiver using an HB100 and a commercial FM radio receiver to find the signal on receive.[5] The radio has a range of "a few blocks" but illustrates another opinion that there is X band power here that can be used.

After studying the data sheet I decided the module already had everything needed for these requirements except a power source, an output for an SMA connector and an enclosure.[6] This design adds that power source and taps the DRO feed line to the transmit antennas for an SMA connector output.

The schematic for the 10 GHz source is shown in Figure 1. The parts list is given in Table 2.

Build and Tune

Figure 2A shows the DRO side of my HB100 circuit board, with the metal cover removed. The white cylinder in the upper left is the DRO. Figure 2B shows the reverse side, where you can see the four elegant patch antennas. Two are located on each end of the board. The HB100 circuit board also has four pairs of two-hole connection points. These are labeled and are located on each corner. The end of the board with the "IF" and "+5V" labels is the transmit end. The holes at the other two corners are both labeled "GND." The pen tip points to a platted through hole that connects to the patch antennas with two symmetric etch runs. This hole is the point where you attach the coax center conductor to pick off the 10 GHz signal to feed the SMA connector. The shield is soldered to the ground plane. Both need to be cleaned of insulation before soldering.

DC Power

Note that in Figure 2B the word "DEAD" is written on my SN1 unit next to the receive antennas. This is because I did not pay careful attention to the data sheet that states that +5.25 V dc is the maximum supply voltage. These units die quickly with too high a supply voltage. I suggest you buy a spare HB100 when you build this project.

A simple LM7805 or similar three terminal regulator works fine to bring a 9 V battery, a 12 V battery or power supply to 5 V. You can add capacitors for input and output filtering but I agree with the TI data sheet for the regulator, and did not.[7]

The power connections are made to the corners of the HB100 board. These are labeled "+5V" and "GND" on the antenna side of the board. The RF and power connections are shown in Figure 3.

RF Connections

To test whether or not your X-band rig can hear, this project is a good source of radiated RF, and the antenna structure and

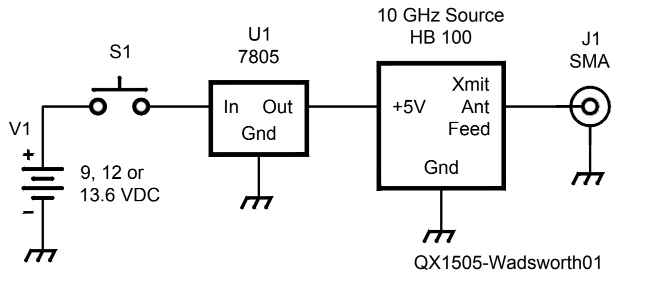
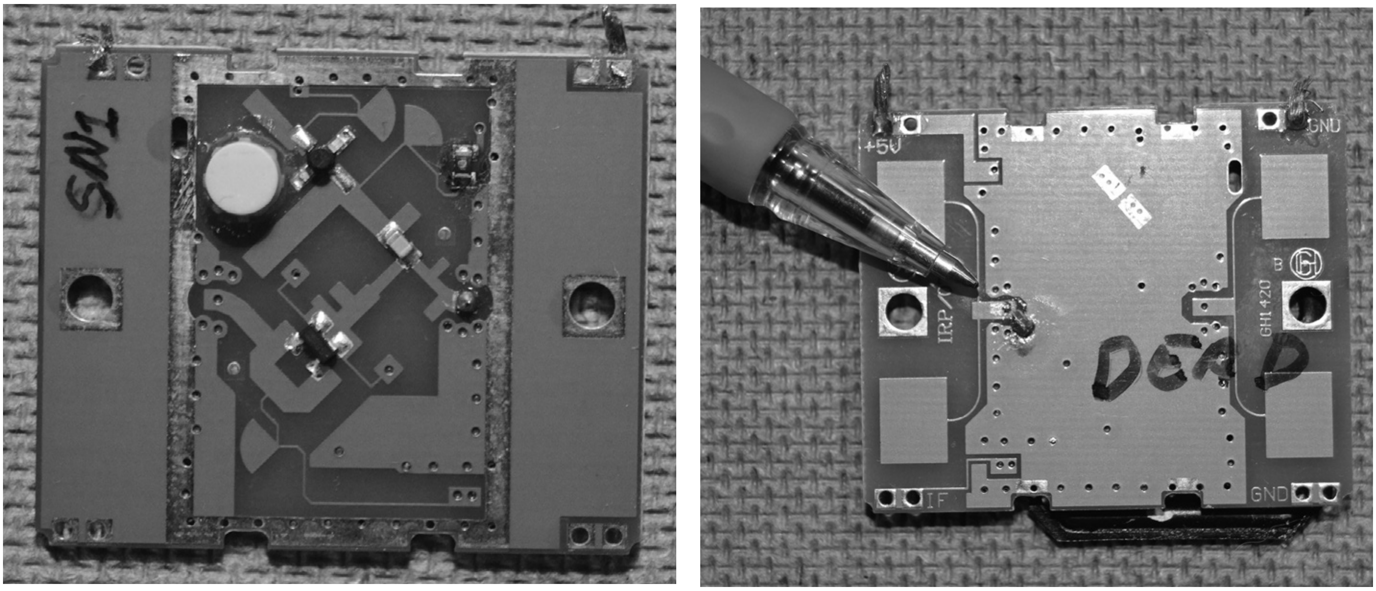


Figure 1 — Here is the schematic diagram of the $25 X-band source.



(A) (B)

Figure 2 — Part A is the component side of my HB100 circuit board, with the metal cover removed. The white cylinder at the upper left side is the dielectric resonator oscillator (DRO). Part B shows the reverse or antenna side of the HB100 board, with the coax attachment point at the tip of the pen. The HB100 is sensitive to V_{CC} overvoltage, which is how this one came to be labeled "DEAD."

feed line is already on the board. Make sure the transmit antennas face outward in your box, or whatever package you use.

For the RF tap to feed the SMA connector, use a short piece of small diameter coax. Don't ask your friends if you can use coax at microwave frequencies; you can. Ideally it should be short in length (a few inches). I used RGS-178 because I had it, but the exact type of coax is not critical. If it's longer you lose more power. You could use semi-rigid cable, but it's harder to work with in this design.

Carefully scrape the green insulation off both sides of the connection point on the HB100. This point is a plated through hole where the two feed lines split off for the two transmit antennas. (These are patch antennas and look like solid rectangles.) Figure 2B shows this point on the antenna side of the board. Note the pen is pointing to the plated through hole for the center connection of the coax. The coax shield gets soldered to the ground plane. It is probably easier to solder the center wire of the coaxial cable on the other side of the board.

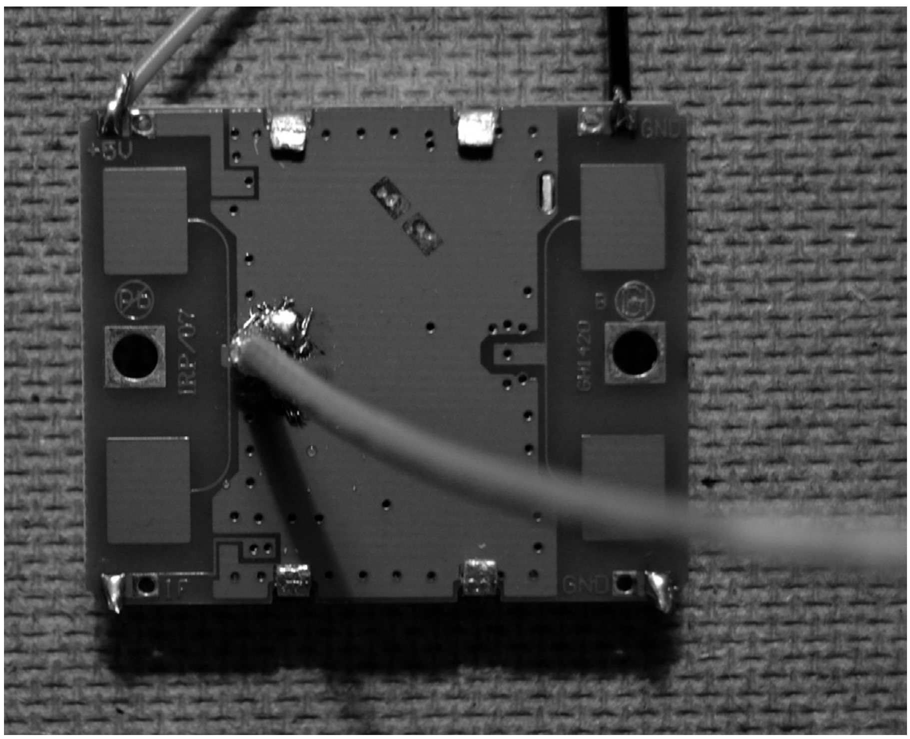


Figure 3 — Here you can see the coax, +5 V dc power, and ground leads attached to the HB100 board.

Frequency Tuning

Now — hopefully — you have a functioning X-band source. To test and tune it you will need a detector of some type. If you already have a 10 GHz Amateur Radio rig, that will work fine. A power meter that covers X band connected through a 10.368 GHz filter will also work. If you don't tune it at all the frequency will probably be where the manufacturer said it would be, between 10.52 and 10.53 GHz.

Tuning is accomplished by turning a set screw in the metal cover on the HB100. If you have a new HB100, the set screw is probably covered by a paper sticker marked "QC." In Figure 4 the pen is pointing to the set screw. Tune your rig to about 10.369 GHz and turn the screw slowly until you detect the signal. It will sound like noise. For future reference note how it sounds in your rig.

Packaging

The package is up to you. I built one unit for bench use without a power supply or enclosure. The unit I use in the field is shown in Figure 5. The board is housed in a plastic box and mounted to the clear plastic lid with

4-40 machine screws and nuts. The 9 V battery is duct-taped to the back.

Using the 10 GHz Source

When packed in a small box the source is quite handy. The only control is the on/off button. My main use is to confirm that the rover rig is receiving signals. Press the ON button and you should hear a noise-like signal. In Figure 6 I am testing my X-band roving dish antenna using the signal radiated by the patch antennas. It's a good idea to run this at home and hear what the source sounds like before you take it to the field.

I have also used the SMA output on this source with a power meter to measure loss in multiple cables, an attenuator, and to check the SWR of two X-band antennas.

Results Compared to Requirements

- $25 cost: The parts cost as listed in Table 2 is $23.16. This buys the parts new. You can cut this below $18 if you already have a project box and a piece of scrap acrylic sheet, or similar material.
- Outputs a signal between 10.368 and 10.370 GHz: Yes, but with only a little more than a milliwatt of power. This worked well for me in field tests during the 2014 10 GHz and Up contest.
- Radiates to free space: Yes.
- SMA output for lab tests: Yes, but the acrylic panel I mounted it on is a little fragile. The side of the project box may be a better choice.
- Small and portable
- Can run off a 9 V battery or 12 V supply: Yes, the LM7805 will handle 8 to 18 V and more.
- Fits in my shirt pocket: Yes, it's snug but fits in mine. You will have to test your own shirt.

I compared the results I measured using the inexpensive 10 GHz source with measurements using my 10 GHz DB6NT G2 based transverter as a signal source. The power measurements were made with an HP 436A power meter and HP power sensor. All were outside their calibration period.

A 6 dB pad measured within about half a dB of its intended value with both sources. Individual cable readings were within 1 dB between the two sources.

I also measured the SWR of two antennas using both sources and a Narda X-band directional coupler. The antennas were a well-executed, homemade X-band horn I bought at the 2012 Microwave Update, and an E-System spiral covering 402 to 19502 MHz. I had never tested SWR on either antenna before.

The SWR results were more interesting than the cables and attenuator. Using either

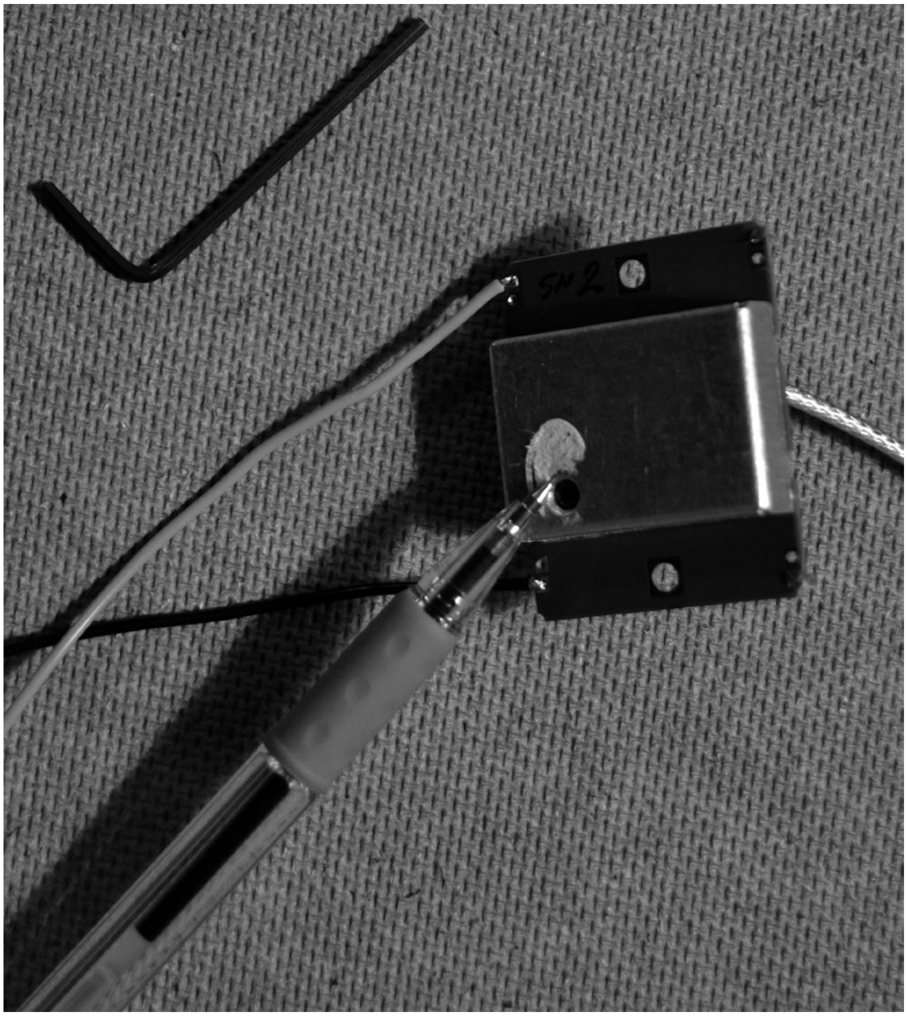


Figure 4 — The frequency tuning screw is shown at the tip of the pen. Use an Allen key to turn the screw. The white paper cover has been removed.

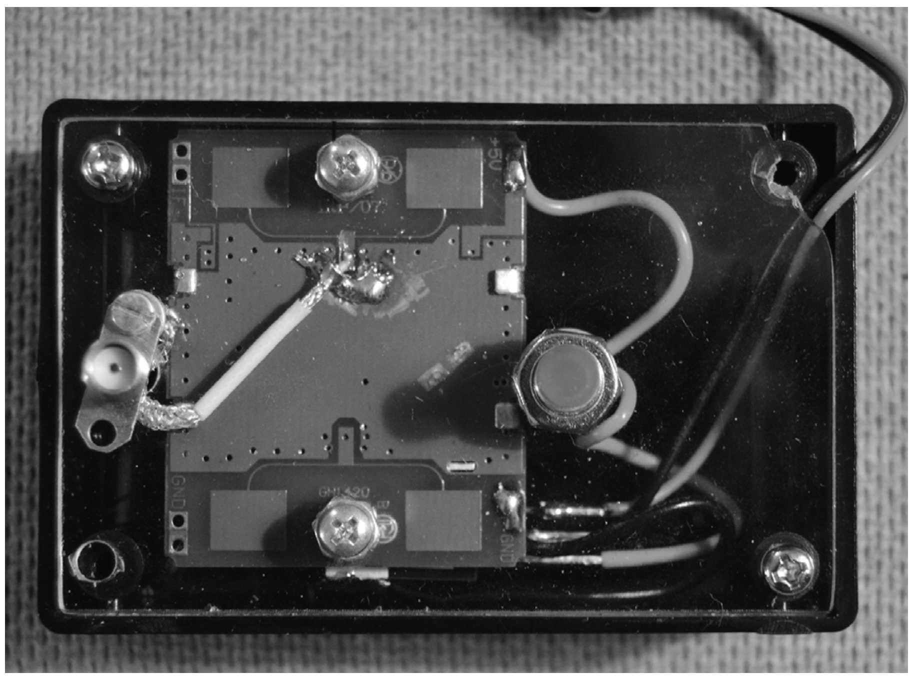


Figure 5 — Here is my 10 GHz source packaged in small plastic box.

Figure 6 — KI5WL testing his rover antenna with the HB100 based source.

source, both antennas looked pretty good. Using the HB100 based source, however, I had power level problems. My DB6NT transverter module puts out about 230 mW of power and my $25 source only puts out about a milliwatt. The Narda coupler port is 20 dB down. If the antenna under test has an SWR of 1.2 (about 21 dB return loss), then to use this source that means you need to be able to measure power levels of at least –41 dBm. That's getting low for my home lab set up.

Using the DB6NT source, the horn and spiral measured an SWR of 1.2 and 1.3 respectively. With the $25 source I could tell both had an SWR better than 2.2, but not how much better.

This source works well for me and is a very low cost unit. If you already have a project box, some scrap cable and a power supply, it can be a $10 unit. You are not going to confuse it with an excellent Keysight signal generator though.

Jeff Wadsworth, KI5WL, was first licensed about 1968 and currently holds an Amateur Extra Class license. He worked in the defense industry for the past 34 years as an electrical and systems engineer, doing RF and missile design. He also teaches systems engineering.

Jeff was a Senior Engineering Fellow and then a Program Director for Raytheon, and a Senior Member of the Technical Staff for Texas Instruments. He is an ARRL Member, a Life Member of the Association of Old Crows and the Society of Amateur Radio Astronomy. He is active in VHF/UHF and microwaves in southern Arizona. Be sure to contact him at ***ki5wl@arrl.net*** *if you want to launch some VHF+ photons and need another station to work!*

Notes

[1]Keysight signal generators are described at **www.keysight.com/en/pc-1000000524%3Aepsg%3Apgr/signal-generator-signal-source?pm=SC&nid=-536902260.0&cc=US&lc=eng**, downloaded September 23, 2014.

[2]For more information about the HB100, go to the manufacturer's website: www.agilsense.com.

[3]Search eBay for "HB100" in Electrical and Test Equipment at **www.ebay.com/** to see what is currently available. The units used in this project were purchased in March, 2014.

[4]Search for "HB100 Doppler sensor" at **www.amazon.com/** to see what is currently available.

[5]Walter Clark, "Inexpensive, Easy to Build Microwave Transceiver," **www.ham-radio.com/sbms/presentations/Walt_Clark/DROplexer.pdf**, downloaded Sep 23, 2014.

[6]HB100 Microwave Sensor Module, ST Electronics, **https://www.openimpulse.com/blog/wp-content/uploads/wpsc/downloadables/HB100_Microwave_Sensor_Module_Datasheet.pdf**, downloaded Sep 23, 2014.

[7]See the second paragraph of the description on page 1 of the TI data sheet for a discussion of bypassing, "LM340-N/LM78XX Series 3-Terminal Positive Regulators," revised December 2013, Texas Instruments, **www.ti.com/lit/ds/symlink/lm340-n.pdf**.